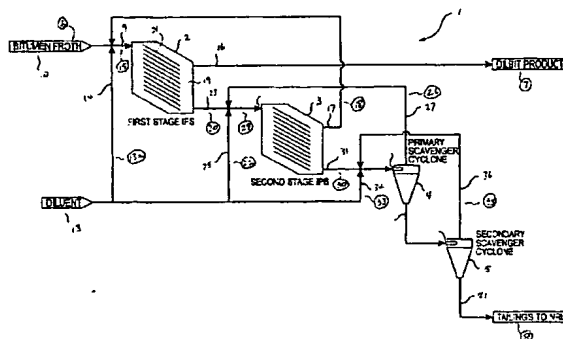(54) CIRCUIT ET PROCEDE D'EPURATION DES MOUSSES DE BITUME DEGAZEES
(54) CIRCUIT AND PROCESS FOR CLEANING DEAERATED BITUMEN FROTH

(57)   Deaerated bitumen froth is cleaned by separating contained bitumen from water and solids contaminants. The froth is countercurrently treated in a three stage circuit comprising primary and secondary inclined plate settlers ("IPS") and a cyclone. Naphtha diluent is added to each of the IPS stages and optionally to the cyclone stage. The combination of increasing diluent/bitumen ratio and separation force is applied to break down emulsion and separate the desired bitumen product from the contaminants.

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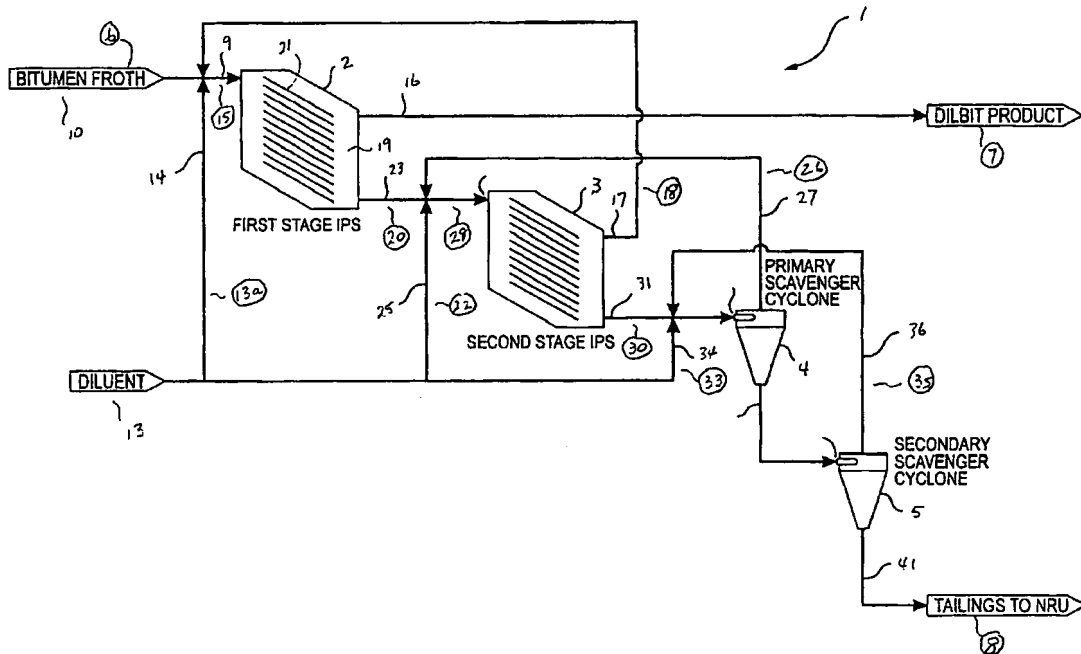(30) Priorité/Priority: 2004/01/21 (2,455,623) CA

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(71) Demandeurs/Applicants:
ROMERO, JOY PATRICIA, CA;
ROMERO, DIEGO LEON, CA;
TAYLOR, KENNETH WAYNE, CA

(72) Inventeurs/Inventors:
ROMERO, JOY PATRICIA, CA;
ROMERO, DIEGO LEON, CA;
TAYLOR, KENNETH WAYNE, CA

(74) Agent: PARLEE MCLAWS LLP

(54) Titre : CIRCUIT ET PROCEDE D'EPURATION DES MOUSSES DE BITUME DEGAZEES
(54) Title: CIRCUIT AND PROCESS FOR CLEANING DEAERATED BITUMEN FROTH

(57) Abrégé/Abstract:
Deaerated bitumen froth is cleaned by separating contained bitumen from water and solids contaminants. The froth is countercurrently treated in a three stage circuit comprising primary and secondary inclined plate settlers ("IPS") and a cyclone. Naphtha diluent is added to each of the IPS stages and optionally to the cyclone stage. The combination of increasing diluent/bitumen ratio and separation force is applied to break down emulsion and separate the desired bitumen product from the contaminants.

"CIRCUIT AND PROCESS FOR CLEANING DEAERATED BITUMEN FROTH"

ABSTRACT OF THE DISCLOSURE

Deaerated bitumen froth is cleaned by separating contained bitumen

5   from water and solids contaminants. The froth is countercurrently treated in a

three stage circuit comprising primary and secondary inclined plate settlers

("IPS") and a cyclone. Naphtha diluent is added to each of the IPS stages

and optionally to the cyclone stage. The combination of increasing

diluent/bitumen ratio and separation force is applied to break down emulsion

10   and separate the desired bitumen product from the contaminants.

1 **"CIRCUIT AND PROCESS FOR CLEANING DEAERATED**

2 **BITUMEN FROTH"**

3

4 **FIELD OF THE INVENTION**

5 The present invention relates to cleaning deaerated bitumen froth by

6 separating contained water and solids contaminants from the bitumen.

7

8 **BACKGROUND OF THE INVENTION**

9 For many years now, bitumen has been recovered from the Athabasca

10 oil sands formation in Alberta using a water-based extraction and air flotation

11 technique. In greater detail:

12 • the as-mined oil sand is mixed with heated water to produce a

13 slurry containing entrained air bubbles; and

14 • contained bitumen is recovered from the slurry in the form of a froth,

15 by flotation.

16 The froth contains varying concentrations of water and particulate

17 solids contaminants. The solids comprise coarse sand and fine clay particles.

18 A typical froth might comprise:

19 bitumen - 60 % by wt.

20 water - 30 % by wt.

21 solids - 10 % by wt.

22 It is necessary to "clean" the froth by removing as much of the water

23 and solids as one can feasibly manage, to prepare it for downstream

24 upgrading.

1   Before it is cleaned, the froth is substantially deaerated to render it

2 pumpable.

3   The present invention is directed to providing a circuit and process for

4 cleaning deaerated bitumen froth.

5

6   **SUMMARY OF THE INVENTION**

7   As previously indicated, the invention is applied to deaerated bitumen

8 froth, such as that produced by an extraction plant associated with an oil

9 sands facility.

10   The deaerated bitumen froth comprises bitumen, water and coarse and

11 fine solids components, present as a partially emulsified mixture.

12   The purpose of the invention is to maximize recovery of the bitumen

13 from the froth as a discrete product, while simultaneously removing water and

14 solids.

15   The difficulty in achieving this objective lies in the fact that, with some

16 of the mixture, it is relatively easy to separate the components, while with the

17 balance it is progressively more difficult to effectively carry out the separation.

18 Otherwise stated, there exists a spectrum of emulsion and a corresponding

19 progressively increasing difficulty in separating the bitumen from the other

20 components.

21   In a broad sense, the invention presents a countercurrent separation

22 circuit and process wherein:

1   • the deaerated bitumen froth undergoes two stages of gravity settling, in

2   primary and secondary inclined plate separators ("IPS's"), followed by

3   one or more stages of cyclonic separation;

4   • coupled with addition of a light hydrocarbon diluent (preferably

5   naphtha) to each of the gravity settling stages and, optionally, to the

6   cyclonic stage(s) as well.

7   In connection with this process design, the concentration of diluent,

8 expressed as diluent/bitumen ratio ("D/B ratio"), is greater in the secondary

9 gravity settling step than it is in the primary gravity settling step. In other

10 words, the D/B ratio is progressively increased as the water and solids in the

11 emulsion being treated is more tightly bound with the bitumen. In conjunction

12 with increasing the D/B ratio, the separation force applied is increased, as the

13 froth is subjected initially to gravity settling (1g) and then to cyclonic

14 separation (100's of g's).

15   By having the capability to deliver diluent separately to each of the

16 stages, it is possible to split the overall diluent addition needed for the process

17 between the stages. As a result, more diluent can be allocated to a later

18 stage if the emulsion being treated in the later stage is proving difficult to

19 separate. This provides flexibility to the process.

20   In one embodiment of the invention, a countercurrent process is

21 provided for recovering bitumen from deaerated bitumen froth containing a

22 mixture of bitumen, water and coarse and fine solids, comprising: providing a

23 froth cleaning process circuit of units comprising primary and secondary

24 inclined plate separators ("IPS's") and a primary cyclone, said units being

1 connected in sequence for enabling three successive stages of separation;

2 providing a source of light hydrocarbon diluent connected to supply diluent as

3 required to each of the units; feeding froth, diluent and a recycled secondary

4 overflow from the secondary IPS to the primary IPS and controlling the rate of

5 diluent addition to the primary IPS so as to provide a pre-determined primary

6 diluent/bitumen ("D/B") ratio in the primary IPS, and subjecting the resulting

7 mixture to gravity settling in the primary IPS so as to produce an overflow

8 product and a primary underflow; feeding primary underflow, diluent and a

9 recycled cyclone overflow from the primary cyclone to the secondary IPS and

10 controlling the rate of diluent addition to the secondary IPS so as to provide a

11 secondary D/B ratio in the secondary IPS greater than the primary D/B ratio,

12 and subjecting the resulting mixture to gravity settling in the secondary IPS so

13 as to produce secondary overflow and secondary underflow; feeding

14 secondary underflow to the primary cyclone and subjecting it therein to

15 cyclonic separation to produce primary cyclone overflow and primary cyclone

16 underflow; recycling at least part of the secondary IPS overflow to the primary

17 IPS; and recycling at least part of the primary cyclone overflow to the

18 secondary IPS.

19   In another embodiment, a deaerated bitumen froth cleaning process

20 circuit is provided comprising: a source of deaerated bitumen froth; a source

21 of light hydrocarbon diluent; a primary inclined plate separator ("primary IPS")

22 having an inlet, an outlet for circuit product and an outlet for primary IPS

23 underflow; means, connecting the froth source with the primary IPS inlet, for

24 supplying froth thereto; means, connecting the diluent source with the primary

1 IPS inlet, for supplying diluent thereto; a secondary inclined plate separator

2 ("secondary IPS") having an inlet, an outlet for secondary IPS overflow and an

3 outlet for secondary IPS underflow; means, connecting the primary IPS

4 underflow outlet with the secondary IPS inlet, for supplying primary IPS

5 underflow thereto; means, connecting the secondary IPS overflow outlet with

6 the primary IPS inlet, for recycling secondary IPS overflow thereto; means,

7 connecting the diluent source with the secondary IPS inlet, for supplying

8 diluent thereto; a primary cyclone having an inlet, an outlet for primary cyclone

9 overflow and an outlet for primary cyclone underflow; means, connecting the

10 secondary IPS underflow outlet with the primary cyclone inlet, for supplying

11 secondary IPS underflow thereto; means, connecting the primary cyclone

12 overflow outlet with the secondary IPS inlet, for supplying primary cyclone

13 overflow thereto; and means, connecting the diluent source with the primary

14 cyclone inlet, for supplying diluent thereto.

15

16 **DESCRIPTION OF THE DRAWING**

17 Figure 1 is a simplified schematic flow diagram of a circuit in

18 accordance with the invention; and

19 Figure 2 is a schematic flow diagram of a test circuit used to provide

20 the experimental run data set forth hereinbelow.

21

1 ## DESCRIPTION OF THE PREFERRED EMBODIMENT

2 The invention is based on a process circuit and a combination of steps

3 applied to a specific feedstock (deaerated bitumen froth) for a specific

4 purpose (cleaning the froth).

5 There is an underlying preferred scheme with respect to operating the

6 circuit and process, which is now described:

7 The overall objective of the process is to produce a desired flow rate of

8 clean bitumen for consumption by an upgrader. A naphthenic diluent

9 preferably is used in this process for cleaning bitumen froth, as it provides

10 optimum operating conditions and easy recovery in an upgrader. The design

11 of an upgrader limits the acceptable range of variability in the composition of

12 the naphtha-diluted bitumen (its feed). The composition includes diluent,

13 water and solids in addition to the most important component, bitumen.

14 The amount of diluent is significant with respect to the amount of

15 bitumen. In fact, to ensure that product specification is met, the mass flow of

16 diluent is ratioed to the mass flow of bitumen. This is called a D/B ratio. This

17 key parameter is used in this froth treatment process to control the overall

18 addition of diluent. That is, a desired flow rate of bitumen (froth) is set and the

19 required diluent (to meet the product D/B ratio) is calculated and subsequently

20 fed. Note that the product D/B ratio is equal to the primary IPS D/B ratio

21 because only the primary IPS produces product.

22

1   In the design, the overall D/B ratio is in the range 0.5 − 0.8 and

2   preferably is in the range 0.65 − 0.75. As previously stated, the primary D/B

3   ratio in the primary IPS will closely correspond with the selected overall D/B

4   ratio. The secondary D/B ratio is not set, but will fall in a broad range of 1.0 −

5   4.0, preferably in the range 1.4 − 2.0. These ranges are selected with the

6   objective of achieving a product containing 0.5 − 2% by wt. water and 0.2 −

7   1.5% by wt. solids.

8   It is desirable to directly measure the mass flow of bitumen in the froth.

9   However, due to limitations in instrumentation, it is often necessary to

10   measure the flow of diluted froth (i.e. after the primary diluent flow has been

11   added) and then back-calculate the amount of bitumen. This is easily done

12   with computer control systems in a fraction of a second. Through repeated

13   calculations, the diluent addition is adjusted to zero in on the desired D/B

14   ratio.

15   The process allows the addition of diluent in various locations (e.g.

16   feed to the primary IPS, feed to the secondary IPS and feed to the primary

17   cyclone). Note that regardless of where the diluent is added it will eventually

18   and substantially come out as product. Therefore, for each volume of diluent

19   that is added to one of the feed locations, a similar volume must be subtracted

20   from another feed location in order to ensure that the product D/B ratio

21   remains essentially constant. Note that the larger the change in diluent flows,

22   the longer it will take for the process to re-establish steady-state.

23

1   It is desirable under most conditions to split the diluent addition

2   between the primary and secondary IPS's. While it is technically possible to

3   control the D/B ratio in the secondary IPS (as is done in the primary IPS), it is

4   not practical. The reason is that the feed to the secondary IPS is variable

5   (possibly highly variable if the froth feed composition is changing). Therefore,

6   it is easier to control the split ratio of diluent to the primary versus secondary

7   IPS's. Note that a desired split ratio is first calculated based on expected flow

8   and compositions of the secondary IPS feed. This ratio is then adjusted to

9   zero in on a desired secondary IPS D/B ratio (without causing any significant

10   deviation in the primary IPS product quality).

11   When operating the primary IPS at the desired froth feed rate and D/B

12   ratio, the underflow is drawn away from the IPS at a specific rate. That rate is

13   a ratio of the underflow to feed rates. Any diluted froth/bitumen that is not

14   drawn off as underflow is pushed over the top and is collected as diluted

15   bitumen product. Note that it is desirable to fine tune the underflow of the

16   primary IPS to draw the emulsion out the bottom for additional treatment

17   rather than allowing it to migrate up and into the product. The emulsion (level

18   and thickness) is monitored using a segmented capacitance probe which

19   shows the percentage of water at various heights in the IPS. Note that the

20   absence of an emulsion layer would be represented by a sharp change in

21   capacitance from a low number representing predominately hydrocarbon to a

22   high number representing predominately water. Conversely, a thick emulsion

23   layer would be represented by a gradual change in capacitance from a low

24   number to a high number.

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1   Having reference now to Figure 1, it shows a process circuit in broad

2   and simplified outline. The invention was tested in a corresponding test circuit

3   1, which is shown in greater detail in Figure 2. This Figure 2 test circuit will

4   now be described, followed by a Table setting forth the composition analyses,

5   D/B ratios and results of an experimental run. It will be noted that neither

6   Figure 1 or Figure 2 show equipment such as pumps, valves or meters. It is

7   expected that one skilled in the art will insert such equipment as required.

8   The test circuit 1 comprised a primary IPS 2, a secondary IPS 3, a

9   primary cyclone 4 and an optional secondary cyclone 5 which could be used

10 in or closed out of the circuit. These units were connected in sequence for

11 enabling three or, if desired, four successive stages of separation. The circuit

12 was countercurrent in design. It was adapted to clean deaerated bitumen

13 froth 6 in stages by separating the hydrocarbons (bitumen and diluent) from

14 the water and solids components to separately recover a diluted bitumen

15 product 7, containing small residual amounts of water and solids, and a water

16 and solids tailings 8, containing a small content of residual hydrocarbons.

17   A source 10 of deaerated bitumen froth 6 was provided. This source

18 was a bitumen extraction plant in an oil sands facility. The froth 6 comprised

19 a partly emulsified mixture of bitumen, water and particulate solids comprising

20 coarse sand and clay fines.

21   The froth source 10 was connected by line 11 with a primary mixer 12.

22 The mixer 12 was connected by line 9 with the inlet of the primary IPS 2.

23   A source 13 of hydrotreated naphtha was connected by a line 14 with

24 the primary mixer 12, for supplying primary diluent 13a thereto.

1   The overflow 18 from the secondary IPS 3 was recycled through line

2   17 to the primary mixer 12.

3   The primary mixer 12 was equipped with an impellor and functioned to

4   blend the viscous froth 6 and primary diluent 13a. Recycled secondary IPS

5   overflow 18 was added to produce a resulting mixture 15 fed to the primary

6   IPS 2 through line 9.

7   The primary IPS 2 was conventional in design. It contained a plate

8   pack 21 of 96 parallel plates of size 3150 x 610 mm spaced apart 38 mm and

9   angled at 55°. The vessel was sized to accommodate a feed rate up to

10   47m³/h. Overflow was controlled by a weir.

11   The primary IPS was operated by controlling the D/B ratio of the feed

12   15, the feed flow and the underflow. The D/B ratio was controlled with the

13   objective of ensuring that the product was within the specification for

14   contaminants. The feed flow was controlled with the objective of ensuring that

15   the IPS loading rate was low enough so that the desired froth cleaning was

16   realizable. And the underflow was controlled with the objective of ensuring

17   that the water, solids and emulsions were drawn away from the product. The

18   overflow was not directly controlled as the liquid level was set by the overflow

19   weir. In addition it was an objective to keep the top level of the emulsion zone

20   below the bottom of the plate pack 21, using the information from a

21   capacitance probe positioned in the IPS.

22   The primary diluted bitumen product 7 was produced as overflow from

23   the primary IPS 2 through line 16.

24

1   The primary IPS underflow 20 was conveyed through line 23 to a

2   secondary mixer 24. Secondary diluent 22 was pumped through line 25 to the

3   secondary mixer 24. And primary cyclone overflow 26 was recycled through

4   line 27 to the secondary mixer 24. The three streams were blended in the

5   mixer and the resulting mixture 28 was fed through line 29 to the inlet of the

6   secondary IPS 3.

7   The secondary IPS 3 was identical to the primary IPS 2.

8   The secondary IPS was operated by controlling the primary/secondary

9   diluent split with the objective of ensuring that a D/B range within the desirable

10   range previously given was achieved. The underflow was controlled with the

11   objective of ensuring that the water, solids and emulsions were drawn down.

12   The overflow was not directly controlled as the liquid level was set by the

13   overflow weir. In addition it was an objective to keep the top level of the

14   emulsion zone below the bottom of the plate pack, using the information from

15   a capacitance probe positioned in the IPS.

16   As previously mentioned, the secondary IPS overflow 18 was recycled

17   to the primary IPS 2.

18   The secondary IPS underflow 30 was conveyed through line 31 to the

19   inlet of a tertiary mixer 32. Tertiary diluent 33 could be fed through line 34 to

20   the mixer 32. And overflow 35 from the secondary cyclone 5 was recycled

21   through line 36 to the mixer 32. These three streams were blended in the

22   mixer 32 and the resulting mixture 37 fed through line 38 to the inlet of the

23   primary cyclone 4.

24   The primary cyclone 4 was a Krebs g-Max (trade-mark) cyclone.

1   The primary cyclone 4 was operated by controlling the feed pressure.

2   Maintaining a target feed pressure maintained g forces, which enhanced

3   emulsion breaking and rejection of unwanted water and solids to the

4   underflow.

5   As previously indicated, the overflow 26 from the primary cyclone 4

6   was recycled to the secondary IPS 3.

7   The underflow 40 from the primary cyclone 4 could be fed directly

8   through line 41 to the inlet of the secondary cyclone 5, which was similar to

9   the primary cyclone 4. The secondary cyclone overflow 35 was recycled to

10   the primary cyclone 4 and its underflow was produced as circuit tailings 8.

11   The secondary cyclone was also operated by controlling the feed

12   pressure.

13   An experimental run was conducted in the test circuit 1 and yielded the

14   following data:

Stream #	Stream Description	Flow t/h	Water wt %	Bitumen wt %	Diluent wt %	Mineral wt %	D/B Ratio
6	Froth Feed	13.17	34.21	62.31	0	3.48	0
	Total Diluent	5.22	0.10	0	99.10	0	n/a
13a	Primary Diluent	2.00	0.10	0	99.10	0	n/a
	Diluted Froth Feed	15.17	29.71	54.09	13.18	3.02	0.24
15	Primary IPS Feed	23.32	20.24	48.55	29.07	2.15	0.60
7	Primary IPS Overflow Product	13.42	0.65	60.69	38.34	0.32	0.63
20	Primary IPS Underflow	9.90	46.80	32.09	16.50	4.62	0.51
22	Secondary Diluent	3.20	0.10	0	99.10	0	n/a
28	Secondary IPS Feed	18.29	33.13	26.17	37.08	3.62	1.42
18	Secondary IPS Overflow	8.15	2.63	38.23	58.62	0.52	1.53
30	Secondary IPS Underflow	10.14	57.65	16.47	19.78	6.10	1.20
33	Tertiary Diluent	0.02	0.10	0	99.10	0	n/a
37	Primary Cyclone Feed	15.31	42.61	23.03	29.57	4.78	1.28
26	Primary Cyclone Overflow	5.19	27.46	31.03	37.57	3.94	1.21
40	Primary Cyclone Underflow	10.12	50.38	18.93	25.47	5.22	1.35
	Secondary Cyclone Feed	10.27	51.14	18.64	25.08	5.14	1.35
35	Secondary Cyclone Overflow	5.14	12.94	36.10	48.76	2.19	1.35
8	Secondary Cyclone Underflow	5.14	89.33	1.17	1.41	8.09	1.20

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1.   A countercurrent process for recovering bitumen from deaerated

5   bitumen froth containing a mixture of bitumen, water and coarse and fine

solids, comprising:

providing a froth cleaning process circuit comprising primary and

secondary inclined plate separators ("IPS's") and a primary cyclone, said

units being connected in sequence for enabling three successive stages of

10   separation;

providing a source of light hydrocarbon diluent connected to

supply diluent as required to each of the units;

feeding froth, diluent and a recycled secondary overflow from

the secondary IPS to the primary IPS and controlling the rate of diluent

15   addition so as to provide a pre-determined primary diluent/bitumen ("D/B")

ratio in the primary IPS, and subjecting the resulting mixture to gravity

settling in the primary IPS so as to produce an overflow product and a

primary underflow;

feeding primary underflow, diluent and a recycled cyclone

20   overflow from the primary cyclone to the secondary IPS and controlling the

rate of diluent addition to the secondary IPS so as to provide a secondary

D/B ratio in the secondary IPS that is greater than the primary D/B ratio,

and subjecting the resulting mixture to gravity settling in the secondary IPS

so as to produce secondary overflow and secondary underflow;

feeding secondary underflow to the primary cyclone and subjecting it therein to cyclonic separation to produce primary cyclone overflow and primary cyclone underflow;

recycling at least part of the secondary IPS overflow to the

5   primary IPS; and

recycling at least part of the primary cyclone overflow to the secondary IPS.

2.   A deaerated bitumen froth cleaning process circuit comprising:

10   a source of deaerated bitumen froth;

a source of light hydrocarbon diluent;

a primary inclined plate separator ("primary IPS") having an inlet, an outlet for circuit product and an outlet for primary IPS underflow;

means, connecting the froth source with the primary IPS inlet,

15   for supplying froth thereto;

means, connecting the diluent source with the primary IPS inlet, for supplying diluent thereto;

a secondary inclined plate separator ("secondary IPS") having an inlet, an outlet for secondary IPS overflow and an outlet for secondary

20   IPS underflow;

means, connecting the primary IPS underflow outlet with the secondary IPS inlet, for supplying primary IPS underflow thereto;

means, connecting the secondary IPS overflow outlet with the primary IPS inlet, for recycling secondary IPS overflow thereto;

means, connecting the diluent source with the secondary IPS

inlet, for supplying diluent thereto;

a primary cyclone having an inlet, an outlet for primary cyclone

overflow and an outlet for primary cyclone underflow;

5   means, connecting the secondary IPS underflow outlet with the

primary cyclone inlet, for supplying secondary IPS underflow thereto;

means, connecting the primary cyclone overflow outlet with the

secondary IPS inlet, for supplying primary cyclone overflow thereto; and

means, connecting the diluent source with the primary cyclone

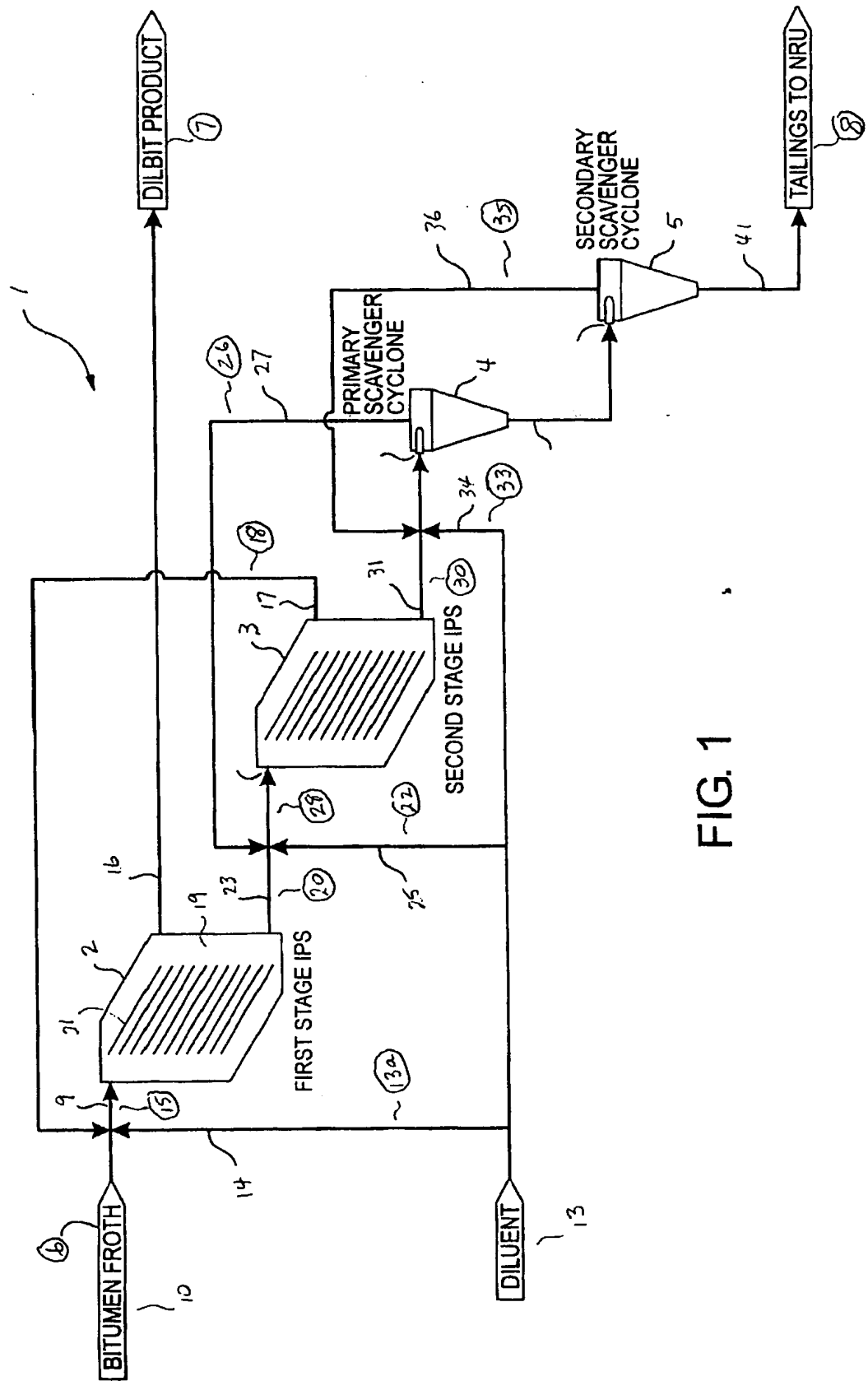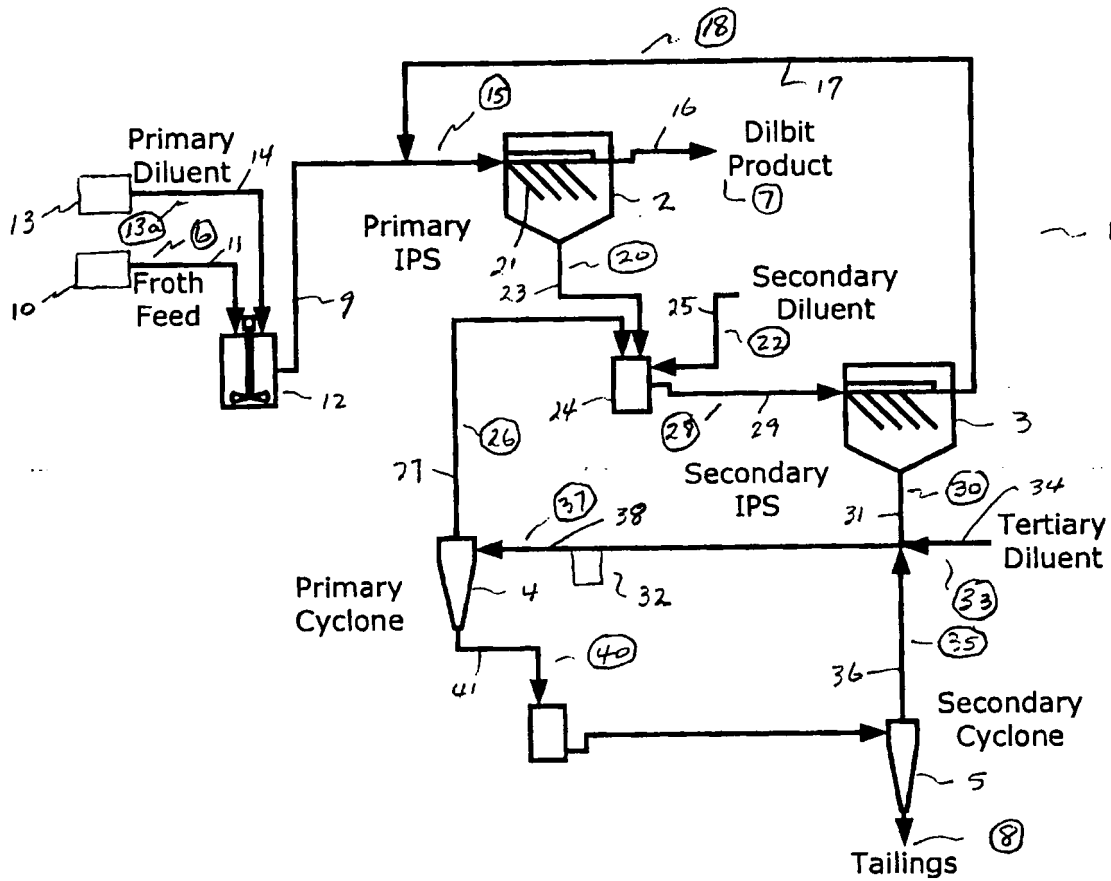10   inlet, for supplying diluent thereto.

FIG. 1

BITUMEN FROTH

DILBIT PRODUCT

TAILINGS TO NRU

DILUENT

FIRST STAGE IPS

SECOND STAGE IPS

PRIMARY SCAVENGER CYCLONE

SECONDARY SCAVENGER CYCLONE

Figure 2: Process Schematic of Test Circuit